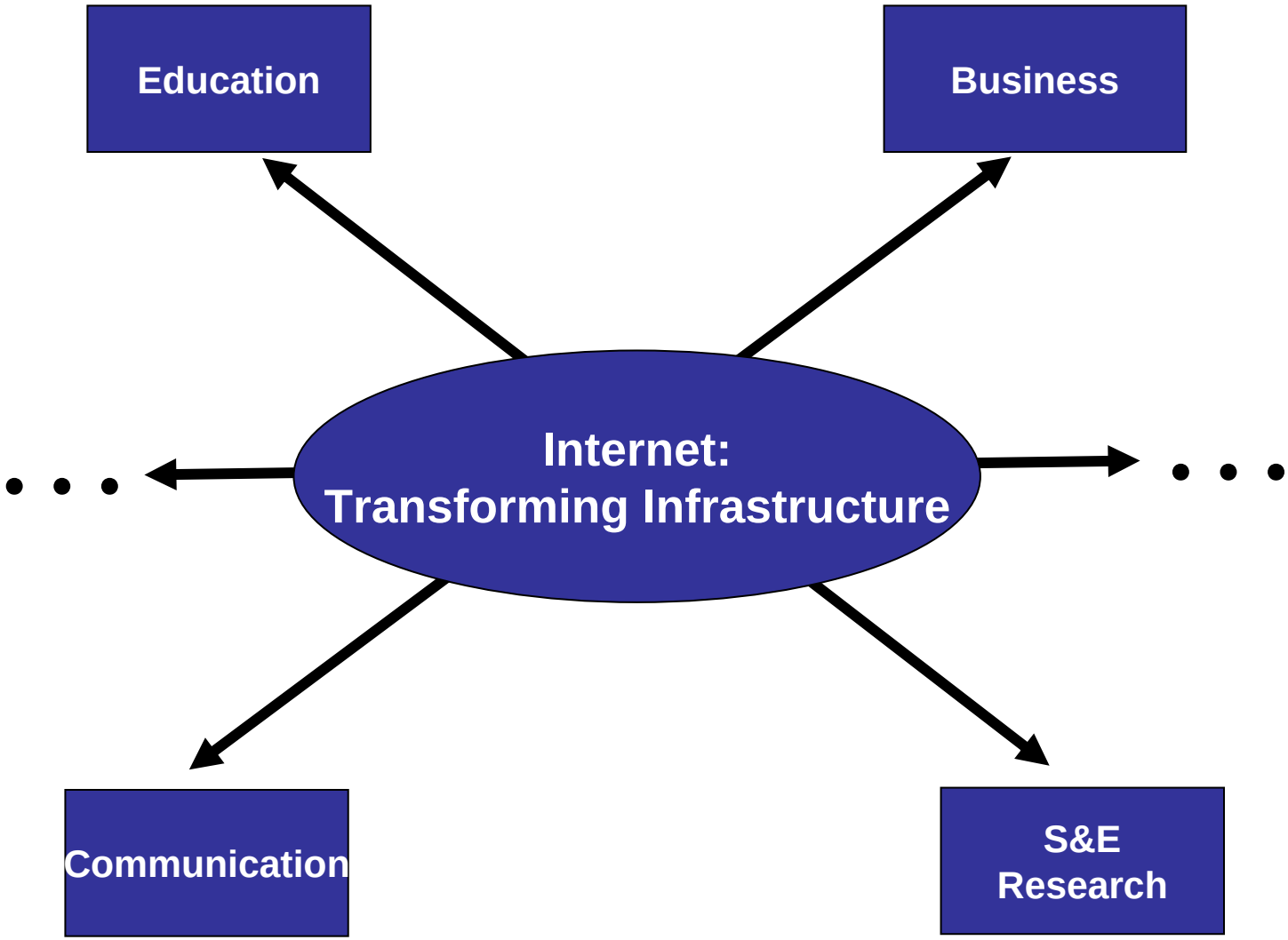
National Science Foundation
WHERE DISCOVERIES BEGIN

The Future Internet: *Can We Get There from Here?*

2006-2007 Topol Lecture
University of Massachusetts, Amherst

Peter A. Freeman
National Science Foundation

September 21, 2006


Education
Business
Internet:
Transforming Infrastructure
Communication
S&E
Research

Astounding changes in scope and impact over the past fifteen (thirty) years, essentially unforeseen by all.

Most astute observers believe that the changes in the future COULD be even greater.

Yet, barriers loom.

Transportation

Critical Infrastructure

Internet Not Ready for Its Future Roles

Telecommunications

Banking & Finance

Images from Google Images

Issues with the Internet

- **Social (e.g. children's use)**
- **Political (e.g. posting false info)**
- **Policy (e.g. access)**
- **Legal (e.g. copyright)**
- **Technical (e.g. security)**

These fundamental issues are closely ***intertwined and must be addressed if we*** *are to realize the opportunities before us.*

What are typical questions?

How can they be addressed?

Policy Issues

NAMING

- Original naming conventions basically developed by Jon Postel and Paul Mockapetris for technical convenience
- Demand for names (domains) grew far beyond any original vision
- Has become an international issue of some heat (and very little light) as a proxy for control
- Is this a technical or a policy issue?
- How does one determine what the possibilities are?
- How can one explore the implications of different choices?

BUSINESS MODELS

- Original model for the Internet had nothing to do with making money - strictly for national defense and research
- Conversion to the public Internet that occurred in the early 1990's was intended fundamentally to remove it from governmental funding and let it stand on its own legs (if possible)
- ISP's don't make enough money to capitalize research and infrastructure extensions
- Common carriers still figuring out how to make money from the Internet
- Do any of the *old* models work?
- Should users pay more for access and use?
- Should those making money on the Internet (e.g. Google) pay?

National Science Foundation
WHERE DISCOVERIES BEGIN

INTERNET GOVERNANCE

- Up to now, it has been "run" by a collection of interdependent forces (technical community (IETF), web operators, ISP's, ICANN, etc.)
- Recently a variety of forces - governments, standards bodies, disaffected groups, companies not making a lot of money, etc. - have asserted the need for different governance
- Comes down to top-down *vs*. bottom-up control
- Could the Internet as we know it exist under a different regimen?
- Are there ways to disentangle the technical issues from the political?
- Is it a global public utility that should be run like any other monopoly utility?
- Could we have simultaneous modalities?

Many other policy issues

- Access - universal or selective?
- Training, esp. in developing societies
- Security - many aspects of security are really policy, not technical, issues
- Privacy - essentially all policy, but driven and enabled by technology
- Differences in customs and traditions
- Net neutrality

Just to name a few!

Legal Issues

COPYRIGHTS

- Digitization has unleashed an incredible amount of creativity and entirely new ways of doing business
- At the same time, entire industries are threatened, with predictable results
- How can current copyright laws take account of new technology?
- What are the appropriate limits on ownership?
- How can we reward creativity without at the same time stifling it (for someone else)?
- Ownership of intellectual property in general

PATENTS

- Business processes can be patented
- Software can be patented
- Much of the software that runs the Internet is subject to patents, though some is open source
- Already some basic processes on the Internet are patented (e.g. 1-click purchases)
- More and more software is patented
- Will this stifle future Internet development?
- What are those things that are truly innovations deserving of a patent?
- How can we balance the common good and future innovation while rewarding present innovation?

JURISDICTION

- The Internet is everywhere and no where!
- No one "owns" it or even significant parts of it
- Yet crimes are committed every second on it, depending on where you sit
- Where is a crime committed?
- Who prosecutes?
- Is it a crime if it is only prohibited at the receiving end?

Many other legal issues

- Spam
- Display of prohibited/offensive items
- Ownership of composite information
- Modification of information
- Educational usage of information
- "Wiretapping" and other snooping
- Differences among legal systems
- Differences among countries

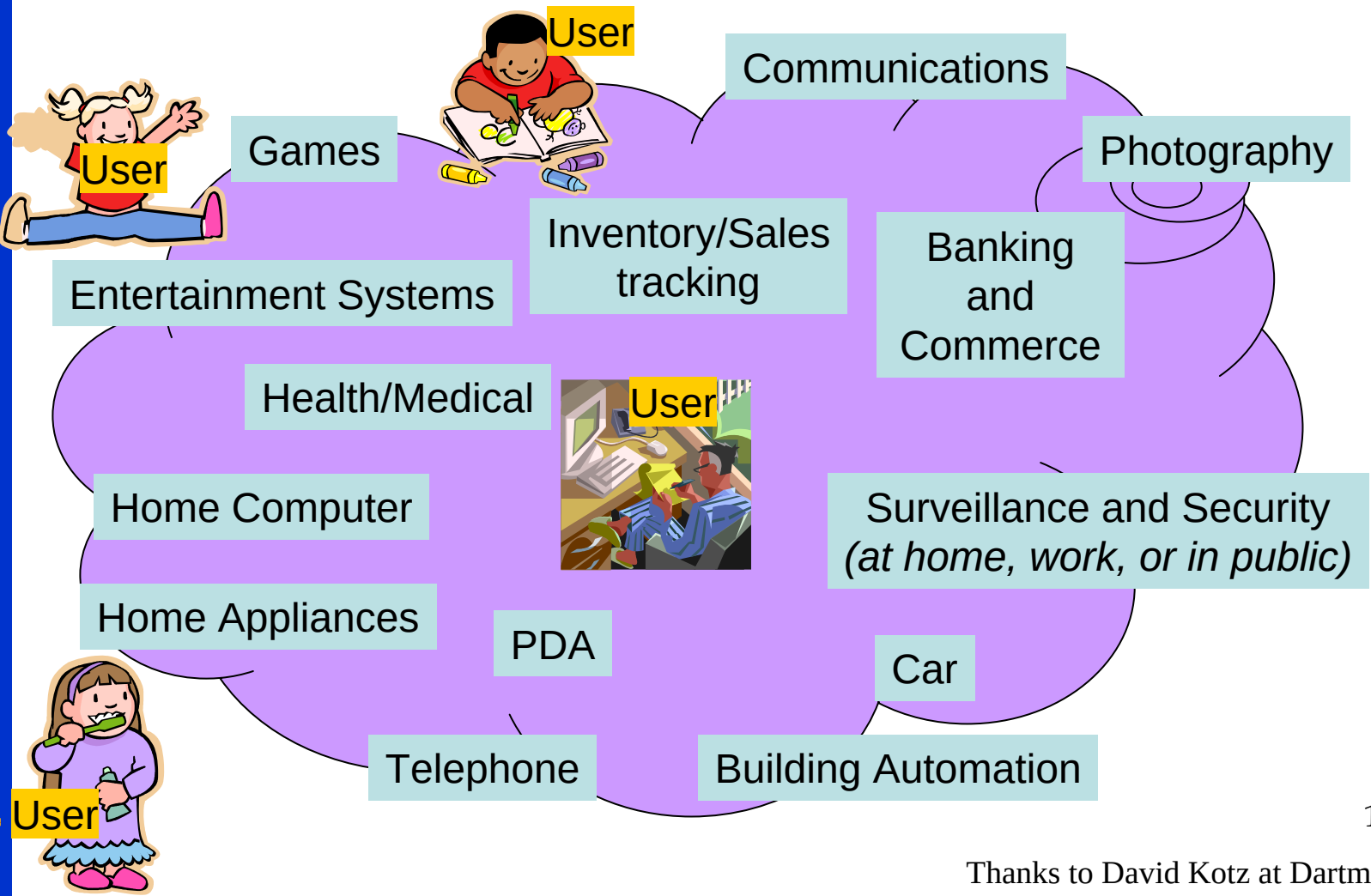
Just to name a few!

Technical Issues

National Science Foundation
WHERE DISCOVERIES BEGIN

Digital Living 2010

Tomorrow's users will be surrounded by pervasive devices, embedded sensors and systems… all connected to the Internet.



Thanks to David Kotz at Dartmouth

The Future Internet

Should

- **Be worthy of our society's trust**
  - Even for managing and operating critical infrastructures
- **Provide a bridge between physical and virtual worlds**
  - Via instrumented and managed sensorized physical environment
- **Support pervasive computing**
  - From wireless devices to supercomputers
  - From wireless channels to all optical light-paths
- **Enable further innovations in S&E research**
  - Seamless access to networked instruments, supercomputers, storage, etc
- **Create a social world in which we would want to live**

Issues with the Internet

- **Security**
- **Robustness**
- **Scaling**
- **Mobile wireless and sensor networks**
- **New technologies**
- **And more!**

There are fundamental issues with the current architecture and many of its mechanisms that cannot be fixed incrementally and with additional engineering workarounds.

National Science Foundation
WHERE DISCOVERIES BEGIN

- **Our challenge (and opportunity!) is to:**
  - Develop new architectures, technologies, and policies
  - Experiment under realistic conditions

Leading to a solid scientific base for future networking and distributed systems that overcome these limitations.

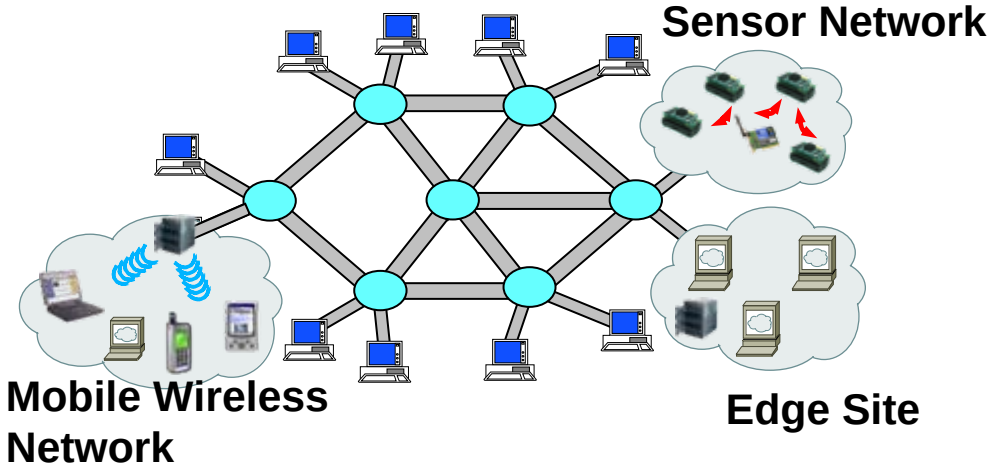
- **Our response is:**
  - Serious experimentation at scale with new architectures, technologies, and policies
  - The GENI Research Program, which will plan and implement this experimental approach
  - The GENI Facility, which will provide the instrument for at-scaled experimentation

GENI Science Plan

- **Community engaged in defining research programs for:**
  - new applications techniques
  - distributed systems
  - network architectures
  - real-time systems
  - wireless networks
  - theoretical descriptions
  - mobile databases . . .

National Science Foundation
WHERE DISCOVERIES BEGIN

The GENI Facility is an advanced, flexible, programmable instrument for networking and distributed systems research.



GENI Facility Will Enable

- Experimentation with complex systems to provide deeper understanding of their dynamics, stability, evolvability, emergent behaviors, and more.
- Evaluation of alternative networking architectures.
- Exploration of the competing goals a network architecture must meet.
- Evaluation of different services.
- In general, to help get us to the Future Internet

Take-aways

- The Internet has accidentally become a public critical infrastructure for modern society (and some not so modern)
- Future opportunities based on networking and distributed systems are potentially far beyond current capabilities
- Exploiting those opportunities is a highly complex, intertwined problem of social, political, policy, legal, economic, and technical issues
- Research at all levels and in all dimensions is necessary to inform the creation of the Future Internet, but may not be sufficient
- The GENI program will enable robust experimentation, eventually in all the relevant dimensions and levels

We can only get to the Future Internet if we invest in the research to get there, but that alone may not be sufficient

For More Information
(starter list)

- **Policy**
  - http://www.oii.ox.ac.uk/research/
  - http://www.issues.org/22.3/p_nelson.html
  - http://www.oecd.org/topic/0,2686,en_2649_37441_1_1_1_1_37441,00.html
  - http://www.state.gov/e/eb/cip/>http://www.state.gov/e/eb/cip/
  - http://www.caida.org/home/ (also technical)
- **Legal**
  - http://cyber.law.harvard.edu/home/
  - http://cyberlaw.stanford.edu/
- **Technical**
  - http://www.nsf.gov/events/event_group.jsp?group_id=4&org=CISE
  - http://www.nsf.gov/cise/geni/
  - http://geni.net/
  - http://www.technologyreview.com/read_article.aspx?id=16356>http://www.technologyreview.com/read_article.aspx?id=16356

National Science Foundation
WHERE DISCOVERIES BEGIN